PEDIATRIC ABUSIVE HEAD TRAUMA

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Phoenix, Arizona

Presented by:

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Pediatric Abusive Head Trauma

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ABUSIVE HEAD TRAUMA

- Leading cause of death due to physical abuse
  - Estimated 35 cases/100,000 infants < 1 yr old
  - Estimated 1200-1400 fatalities/year **
- High incidence of brain injury, psychosocial dysfunction, and physical impairment in survivors
- Most common trigger – crying
- Most common age 3-8 mo
- Perpetrator is usually a parent or caregiver; 65 – 90% male

Risk Factors: Caregiver

- Mental health problems
- Domestic Violence
- Substance abuse
- Stress: lack of family or community support, poverty, single parent, illness, job loss, divorce
- Lack of experience with children
- Lack of prenatal care
- Unrelated adult in home

Risk Factors: Victim

- Young age
- Colic
- Handicapped
- Prematurity
- Multiple births
- Feeding issues
- Toilet training
- “Poor fit”

Risk Factors: Community

- Isolation
- Poverty
- Lack of community resources (recreation, transportation, shopping)
- Violence in community/media

Abusive Head Trauma: Nomenclature

- Early descriptions used mechanistic etiologies such as shaken baby syndrome.
- This implies an unrealistic certainty about the exact mechanism. The AAP now recommends the term abusive head trauma

AAP Policy Statement: Abusive Head Trauma in Infants and Children

Christian and Block, Pediatrics 2009

Legal challenges to the term "shaken baby syndrome" can distract from the more important questions of accountability of the perpetrator and/or the safety of the victim. The goal of this policy statement is ***not to detract from shaking as a mechanism*** of AHT but to broaden the terminology to account for the multitude of primary and secondary injuries that result from AHT.....

Commentary on AAP Policy Statement

While this term's validity as a medical diagnosis deserves further scrutiny, it does appear to acknowledge that the shaking mechanism is no longer thought sufficient to account for the resultant pathology

Gabaeff

Western Journal of Emergency Medicine 12 (2) 2011

- The debate is……..whether SBS exists at all

- It appears that SBS does not stand up to an evidence based analysis

  Gabaeff, *Challenging the Pathophysiologic Connection between Subdural Hematoma, Retinal Hemorrhage and Shaken Baby Syndrome*
  Western Journal of Emergency Medicine 12 (2) 2011

- The scientific underpinnings of SBS have crumbled over the last decade.

  Tuerkheimer, *The Next Innocence Project: Shaken Baby Syndrome and the Criminal Courts*, 87 WASH. U.L. REV. 1, *11 (2009)

- *"Are you aware, Doctor, that the mainstream medical community no longer accepts the **theory** of **Shaken Baby Syndrome?**"*

A Daubert Analysis of Abusive Head Trauma/Shaken Baby Syndrome

Narang, Social Sciences Research Network, 2011

As of 2010 there were:

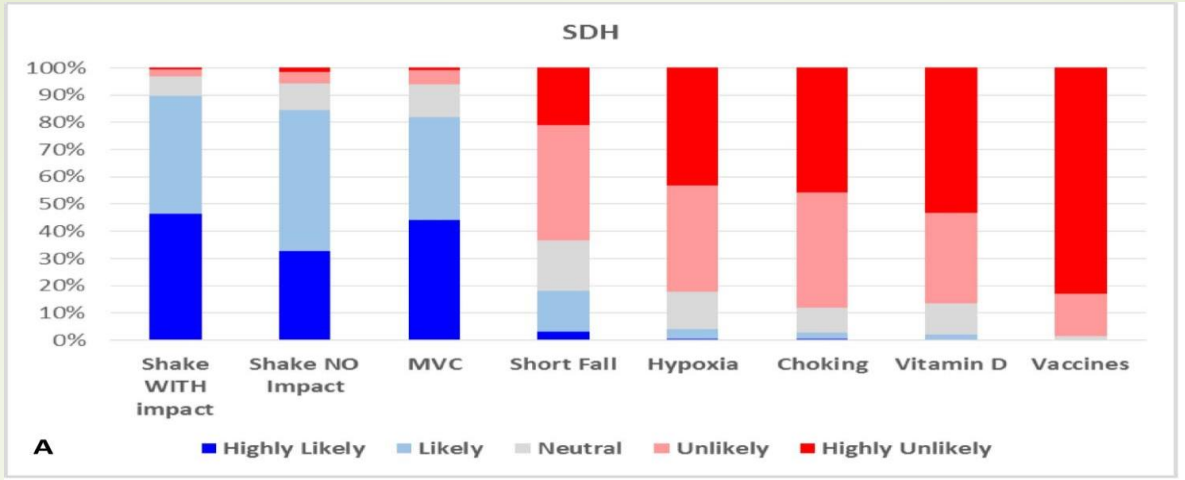
- 2 treatises (880 pages) on Abusive Head Trauma
- 14 chapters (260 pages)in medical textbooks
- Over 700 peer reviewed articles by more than 1000 authors from at least 28 different countries on the topic of Abusive Head Trauma.
- 8 systematic reviews
- 15 controlled trials
- >60 comparative cohort studies or prospective case series
- Numerous well designed retrospective case series or reports

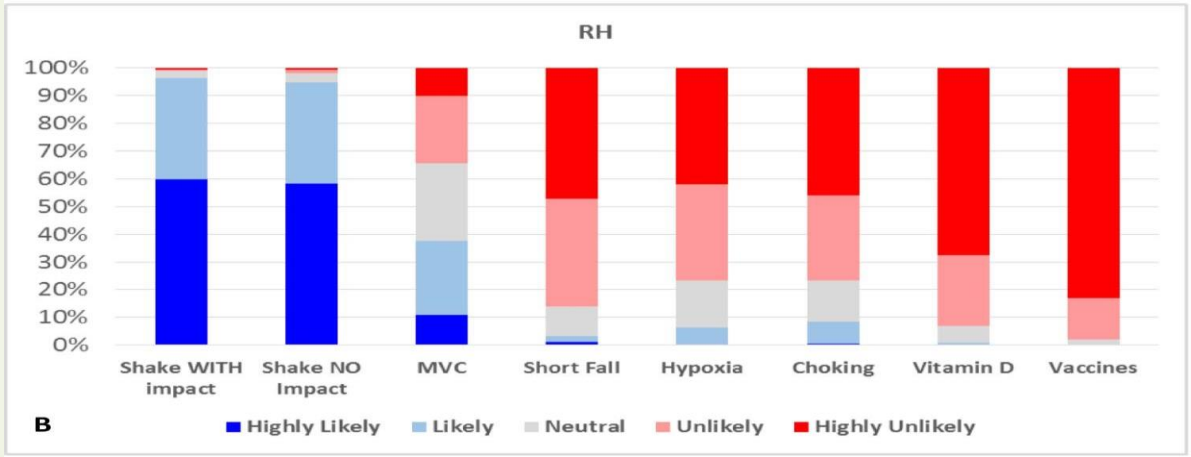
All supporting the diagnosis of AHT

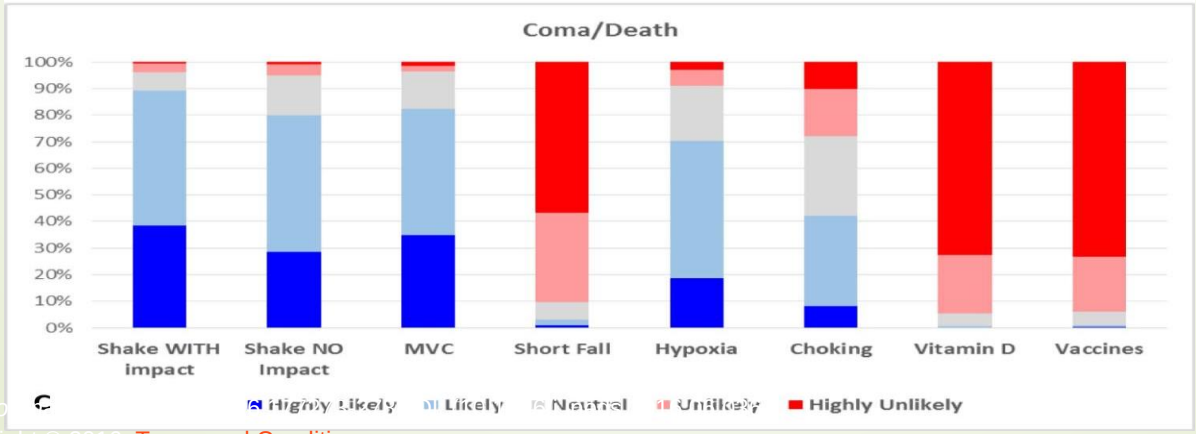
Acceptance of Shaken Baby Syndrome and Abusive Head Trauma as Medical Diagnoses

*** Narang et al
J Peds 2016

- Survey of physicians based in children's hospital as well as MEs; 50% response rate
- Mechanisms: shaking, shaking with impact, short fall, MVC, hypoxia, dysphagic choking, vitamin D deficiency rickets, vaccine reaction
- Outcomes: Severe RH, SDH, coma, death
- Did they believe SBS and/or AHT to be valid medical diagnoses
- Results: 88% believe SBS to be a valid diagnosis; 93% AHT
  - Vast majority of physicians surveyed believed that shaking with and without impact was likely to cause these injuries; short falls, Vit D deficiency, and vaccines were not







Consensus statement on abusive head trauma in infants and young children

Pediatric Radiology 2018

- Endorsed by:
  - Society for Pediatric Radiology
  - European Society of Paediatric Radiology
  - European Society of Paediatric Neuroradiology
  - American Academy of Pediatrics
  - American Society of Pediatric Neuroradiology
  - American Professional Society on the Abuse of Children
  - Swedish Paediatric Society
  - Norwegian Pediatric Association
  - Japanese Pediatric Society
- Review of consensus statements from 15 major national and international professional medical societies and organizations

Consensus Statement Questions

- 1. What are the causes of head injury in infants and young children, and why has the AHT terminology evolved?
- 2. What are the presenting features of AHT?
- 3. How is the diagnosis made?
- 4. What unsubstantiated alternative diagnoses are being offered in the court?
- 5. What is the role of the MDT child protection team in the determination of AHT?
- 6. What are the issues that perpetuate misconceptions in the courts?
- 7. What can be done to provide the courts with accurate information about the state of medical knowledge in AHT?

How does it present

Severe or fatal head injuries will present with symptoms immediately after injuring event

Symptoms in less severe cases may be non specific (irritability/lethargy, vomiting, etc) and may progress or subside.

Lack of specificity may lead to misdiagnosis

How is the diagnosis made?

- History
  - Inconsistent
  - No history of trauma
  - Short fall
- Physical Exam findings
  - Bruising – head, face
  - Ocular findings
  - No external signs of trauma

Diagnosis

- Lab, imaging
  - Coagulation studies, 'bone labs', liver function tests
  - Skeletal survey < 2 yr old
  - CT in children with signs of neurologic impairment, followed by MRI (brain, spine)
  - MRI in children who are neurologically intact

Findings

- Simple (linear) skull fractures – equally common in AHT and accidents
- Complex skull fractures – more common with AHT
- Epidural hematoma – more common with accidental injury
- Subdurals – far more common with AHT
- Subarachnoid, intraventricular, intraparenchymal hemorrhage – equally common in abuse and accidental injuries

Findings

- Venous injury is strongly associated with AHT. This is most common at the junction of the bridging vein and the superior sagittal sinus
- Young infants at increased risk of upper cervical injury – usually ligamentous and *not visible on imaging* except MRI which has shown that up to 78% of these infants have spinal findings, including ligamentous injury and tracking of blood from posterior fossa

Conclusions

- AHT is the most appropriate terms for infants and young children who suffer from inflicted intracranial and spinal trauma
- Lack of history, changing history, or incompatible history raise concern about possible AHT
- Isolated intracranial injuries in AHT cases are uncommon, thus a comprehensive evaluation to rule out other disease process is needed
- No single injury is diagnostic of AHT. Diagnosis is made based on a compilation of injuries
- Each case must be evaluated for other conditions that might present with similar findings. ("is there a medical cause to explain the injuries?")

Conclusions

- No reliable medical evidence that these cause constellation of injuries associated with AHT
  - Cerebral sinovenous thrombosis
  - Isolated HIE
  - Lumbar puncture
  - Dysphagic choking/vomiting
  - Rebleed of birth related SDH leading to collapse, coma, death
- AHT is a medical diagnosis unrelated to the legal determination of a charge of murder
- Consensus statements can educate about what is accurate medical information and what is non evidenced based, speculative, or professionally irresponsible etiologic hypotheses

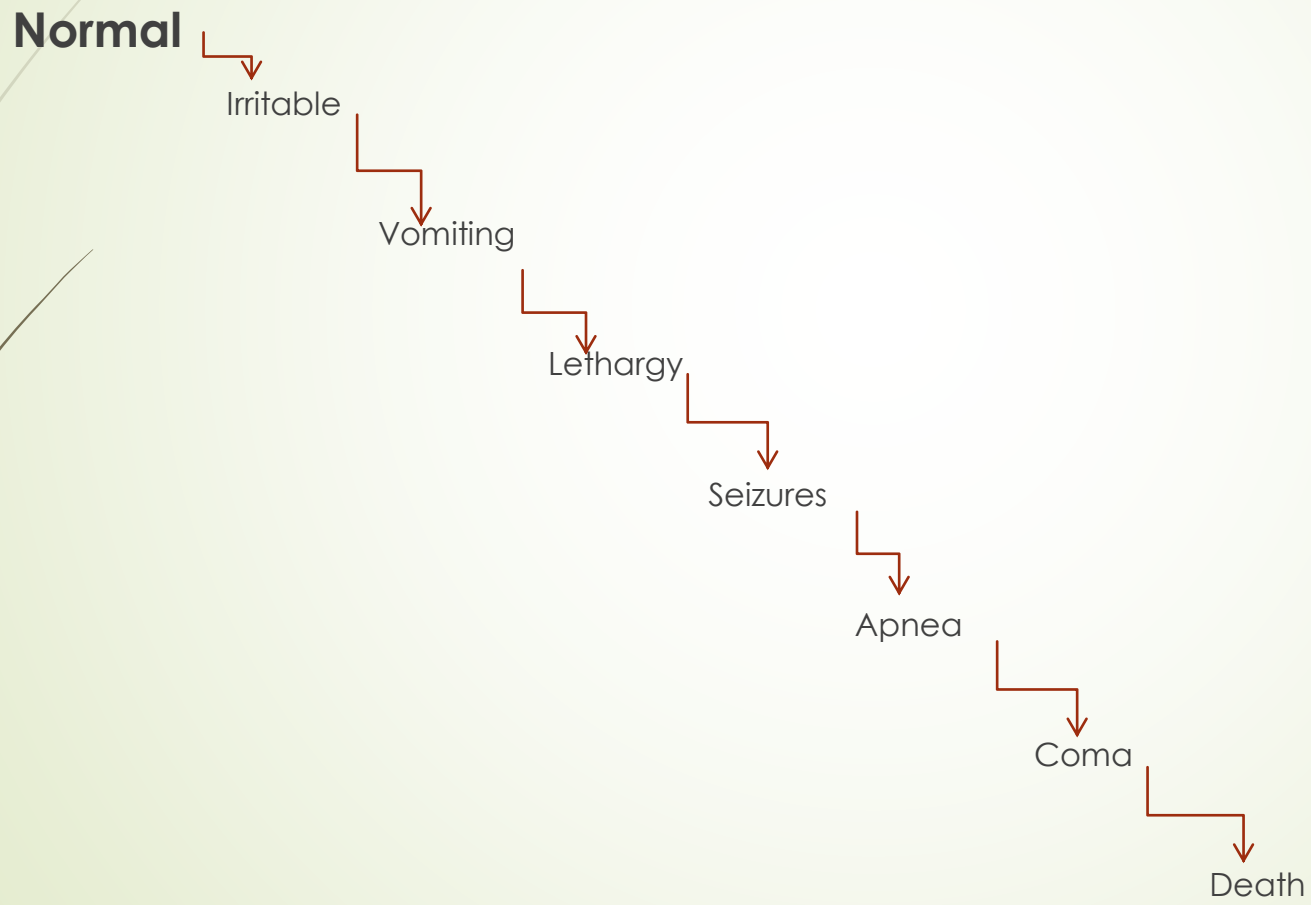
Role of Child Abuse Pediatrician

- Recognize cases of AHT masquerading as accidental
- Recognize cases of accidental head trauma or medical conditions masquerading as abuse
- Direct an appropriate diagnostic evaluation
- Assemble and integrate the relevant history, clinical, lab, and radiologic information
- Formulate a complete differential diagnosis
- Formulate objective forensic impressions of reasonable medical certainly regarding nature, severity, mechanism and timing of child's injuries
- Communicate those impressions clearly, consistently with without bias.

What is Abusive Head Trauma?

- A *range of findings* including:
  - Bruising to the face and scalp.
  - Oral injuries
  - Simple and complex fractures of the skull.
  - Bleeding into the covering of the brain and spinal cord (subdural, subarachnoid, epidural).
  - Injury to the brain tissue; chiefly injury to the connections (axons) between the brain cells as well as hypoxia.
  - Severe brain swelling.
- Associated injuries may include:
  - Retinal hemorrhages
  - Fractures to the ribs and growth plates of the long bones (metaphysis).
  - Acquired bleeding disorder

Clinical Presentation of AHT Victims



Clinical signs and symptoms

- Acute/subacute (immediate to a few hours/days):
  - Soft tissue injuries
  - Inconsolability
  - Lethargy
  - Loss of appetite
  - Vomiting
  - Altered sleep patterns
  - Seizure
  - Altered or loss of consciousness
  - Apnea
  - Arrest

Clinical signs and symptoms

- Late (weeks to years)
  - Feeding difficulty
  - Developmental delay
  - Sensory deficit
  - Motor impairment
  - Macrocephaly
  - Microcephaly
  - Behavior disorders

Pediatric Head Trauma: descriptors

- *Mechanism*
  - Impact
  - Acceleration deceleration (inertial injuries)
  - Asphyxia/hypoxia
  - Neglect
  - Penetrating injury
- *Location*
  - Extracranial (scalp)
  - Cranial
  - Intracranial

Medical Approach to Evaluation

- What are the primary injuries?
- What needed to happen to cause these injuries?
- Does the history provide a plausible explanation?

Biomechanics: contact/impact

- "Translational" forces – straight line in relation to center of gravity.
- Think short fall
- May result in 'impact' injuries such as bruises, skull fracture, epidural hemorrhage, focal subdural hemorrhage
- Not associated with significant brain injury (unless there is a 'space occupying' bleed)

Primary Injuries: Contact/impact

- Soft tissue injuries (bruising, swelling, abrasions)
- Subgaleal hematoma, cephalohematoma
- Skull fracture
- Associated epidural, subarachnoid, subdural hemorrhage, brain contusion or laceration (coup/ contrecoup injuries)

- ***Signs of impact are not always visible in living child; impact can never be definitively excluded. This (absence of external signs of injury) is one of the reasons why AHT is often missed.***

Biomechanics: Inertial (acceleration/deceleration)

- Results from whole head repetitive cranial acceleration or deceleration. Can be induced by forces transmitted through the neck (whiplash), or by cranial impact with resultant cranial acceleration/deceleration.
- The brain spins on its axis, putting tension on the connections between the brain cells (axons).
- In shaking, the head is subject to translational movement in three dimensions, resulting in shearing forces. Impact may occur when the chin hits the chest and the back of the head hits the shoulders.

Primary injuries: Inertial

Axonal injury >> change in level of consciousness, seizures, apnea

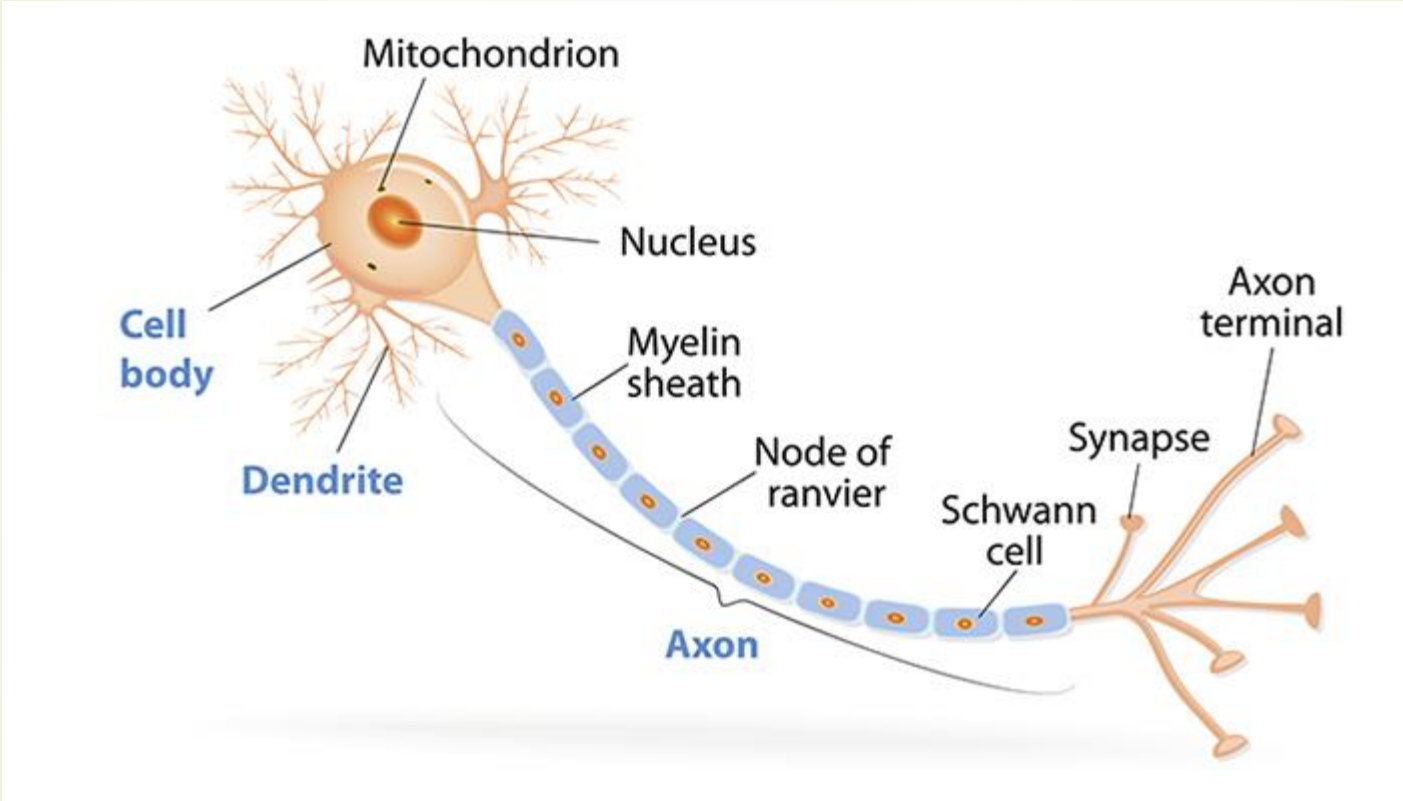
Non focal subdural bleeding from shearing of vessels

Associated subarachnoid hemorrhage, contusion, laceration

Apnea due to brainstem injury

Loss of autoregulation of brain vasculature

- ***The subdural bleeding is an easily detected marker for the underlying brain injury***


Mitochondrion
Nucleus
Cell body
Myelin sheath
Axon terminal
Synapse
Node of ranvier
Dendrite
Schwann cell
Axon

Secondary Brain Injury

- Primary injury to brain tissue may lead to respiratory arrest >> cell death and increased swelling.
- Severe brain swelling>> decreased blood flow to the brain >> impaired delivery of oxygen and glucose.
- Severe brain swelling may cause herniation of brainstem >> injury or death of brain centers vital to survival.
- Post traumatic seizures may compound hypoxic injury
- Loss of autoregulation of brain vasculature
- Metabolic ‘cascade’ that contributes to brain injury

Predisposing Anatomical Features of Infants & Young Children

- Large head relative to body size.
- Relatively weak neck musculature.
- Relative lack of CNS myelination ("squishy brain").
- Immature skeletal structure (many growth centers).
- Infant skull more deformable than adult and can withstand larger shape distortions, leading to brain injury.
- The developing brain sustains greater injury at a lower threshold than adult brain.
- The effects of repetitive impulse loading are cumulative.

Problems with studying infant head trauma

- Properties of the infant head are so variable and forces needed to injure so poorly understood, that answers to how much force is required are not known.
- No one has been able to produce a model that approximates the properties of the infant head.
- Injury thresholds are based on studies in adult primates. These are 'scaled down' for use in children, however this does not account for differences in tissue composition, mechanical properties, and vulnerability of the infant brain

Sentinel Injuries

- A ***sentinel injury*** is defined as an injury suspicious for abuse because the infant was not mobile, or the explanation was implausible.
- Bruising in a non ambulatory infant most common
- Approximately 25 - 30% of abused infants have had sentinel injuries which were noted but overlooked by clinicians or caregivers, leaving children at risk for ongoing abuse

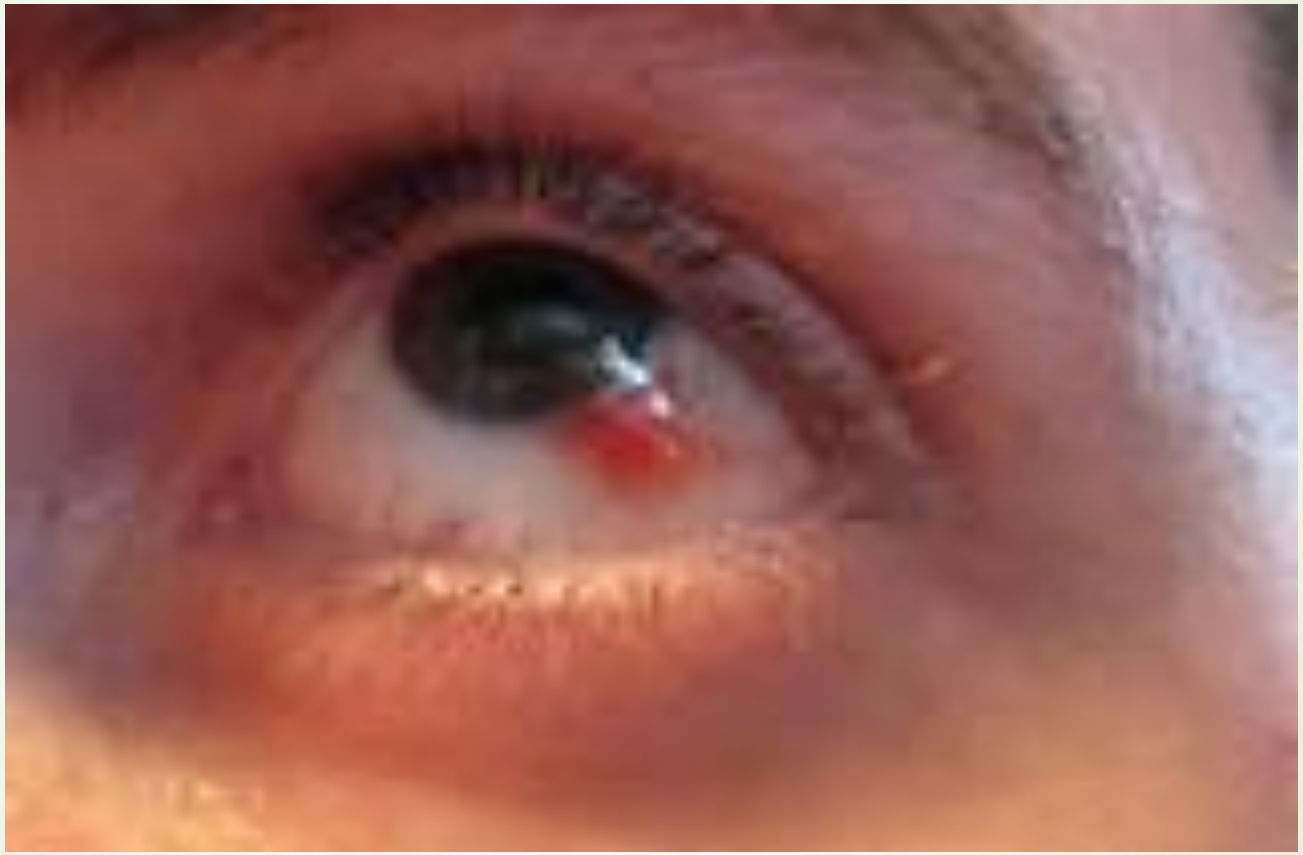
Sentinel Injuries

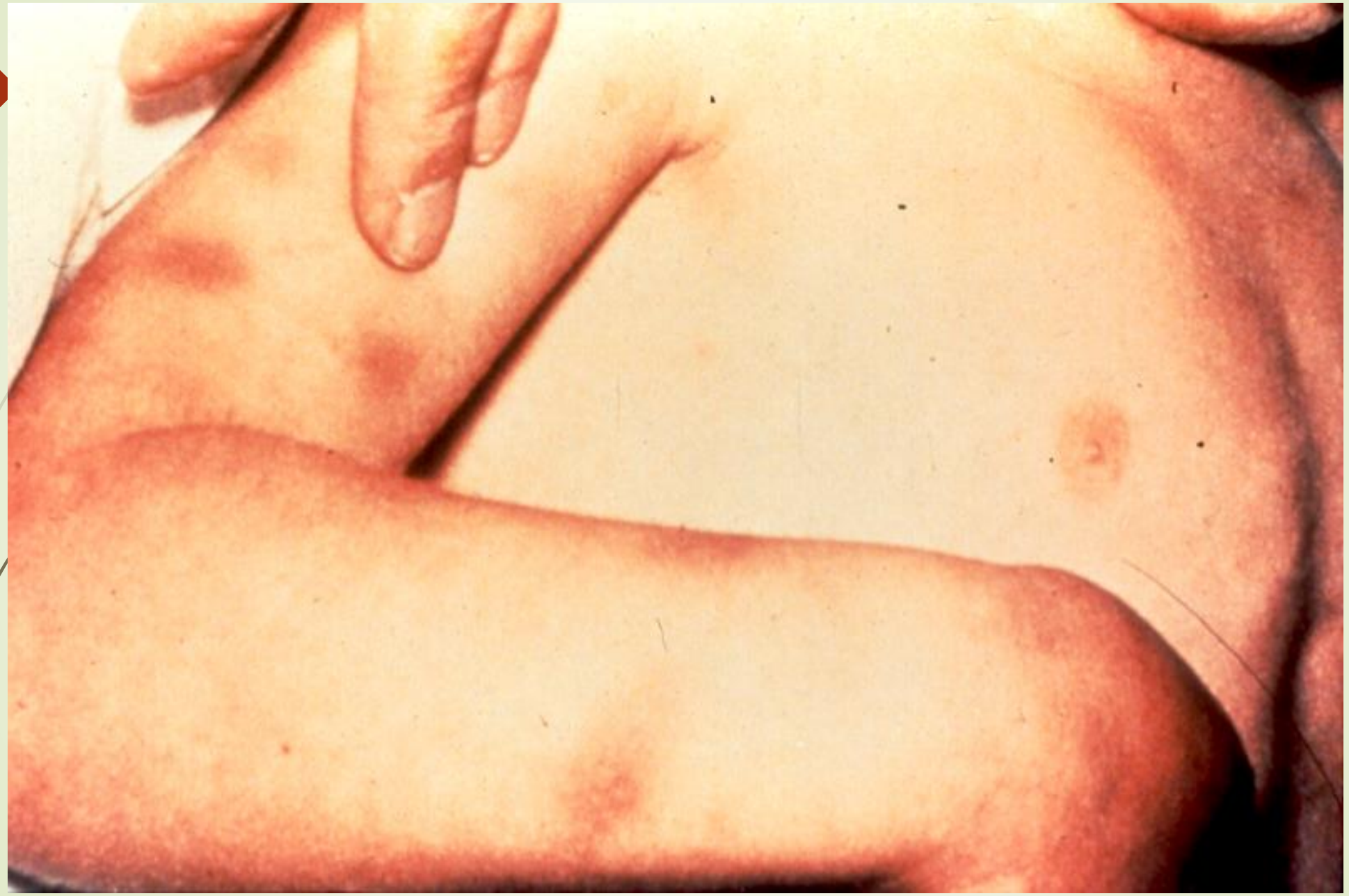
- 401 infants < 12 months of age
  - 200 definitely abused – 27% had a previous sentinel injury
    - 80% bruising
    - 11% intraoral injury
    - 7% other
  - 100 intermediate concern – 8% had previous sentinel injury
  - 101 non abused (controls) – none had previous sentinel injury
- 66 of the sentinel injuries occurred at< 3 months of age
- 95% occurred at < 7 months of age
- In 41.9% of cases, medical providers had been aware of the injury

Sentinel Injuries in Infants Evaluated for Physical Abuse

Sheets et al

Pediatrics April 2013 Vol 131 Issue 4





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Bruising Characteristics Discriminating Physical Child Abuse from Accidental Trauma
Pierce et al Pediatrics January 2010

- **Bruises to:**
  - **T**orso
  - **E**ars
  - **N**eck
  - **F**renulum
  - **A**ngle of jaw
  - **C**heek
  - **E**yelid
  - **S**clera/subconjunctiva
- Any bruise in a child less than **4** months
- **P**atterned

- These have a high positive predictive value for inflicted injury

Missed and Occult AHT

- • Risk of subsequent abuse
  - – 25-30% reinjured prior to ID of abuse
  - – 40% have medical complications related to delay*
- • Seizures, increasing HC, recurrent vomiting
- • 1/3 of high risk (fractures, facial injury, age <6months) physically abused infants & toddlers with no neurologic symptoms have occult head trauma**

*Jenny et al. Analysis of Missed Cases of Abusive Head Trauma JAMA July 7,1999

**Rubin et al. Occult Head Trauma in High Risk Abused Children Pediatrics June 2003

Why are so many cases of AHT missed?

- Absence of visible signs of trauma
- Misleading history
- Non specific signs and symptoms

Timing:
Are Children "Normal Acting" After Severe AHT?

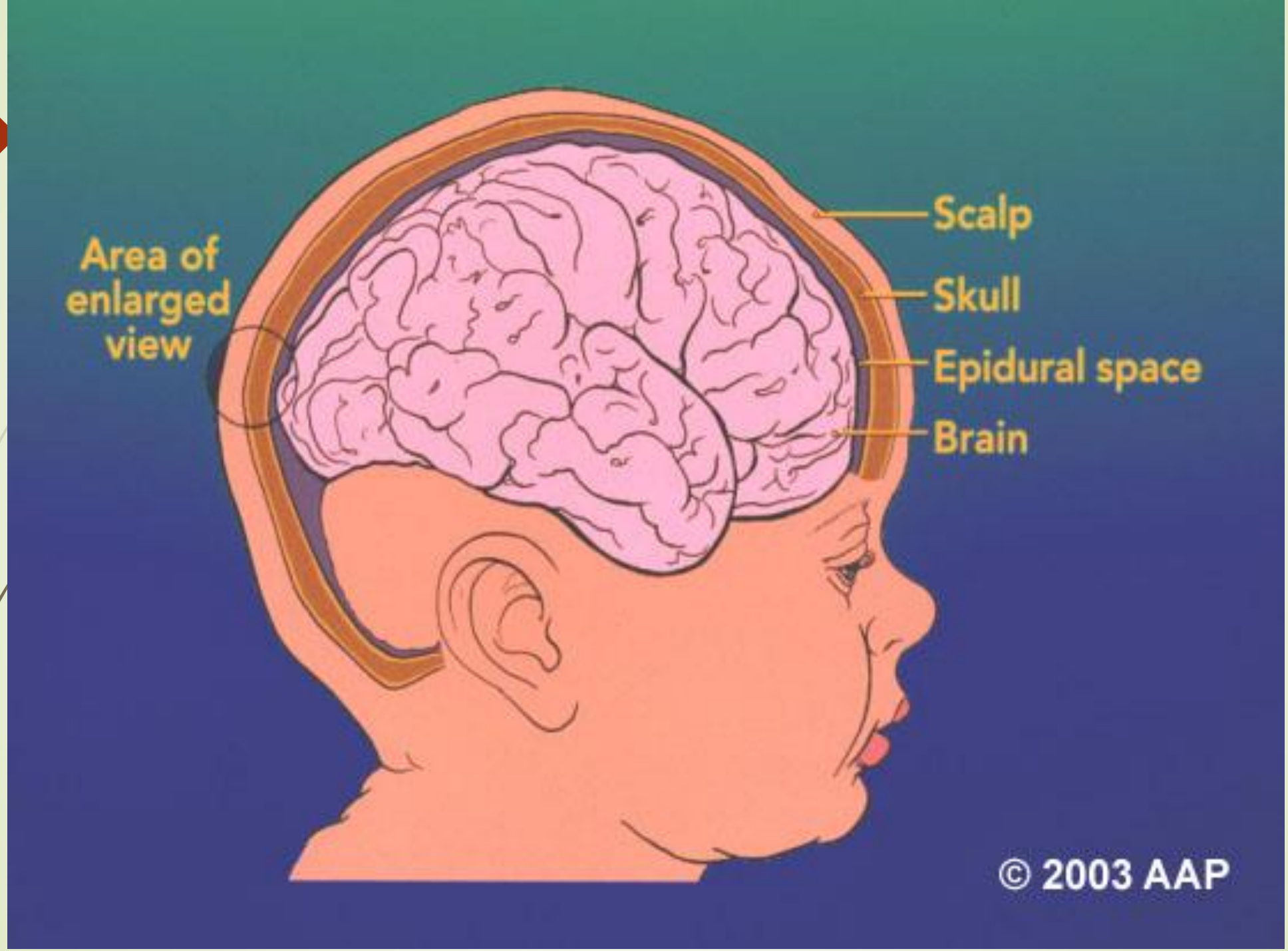
- It is generally accepted that children undergoing severe AHT have symptoms at the time of the injury.
- Perpetrator confessions describe:
  - Infants becoming limp and pale.
  - Respiratory arrest or gasping respirations.
  - "Eyes rolling back in the head."
  - Seizure like activity.
  - Vomiting.

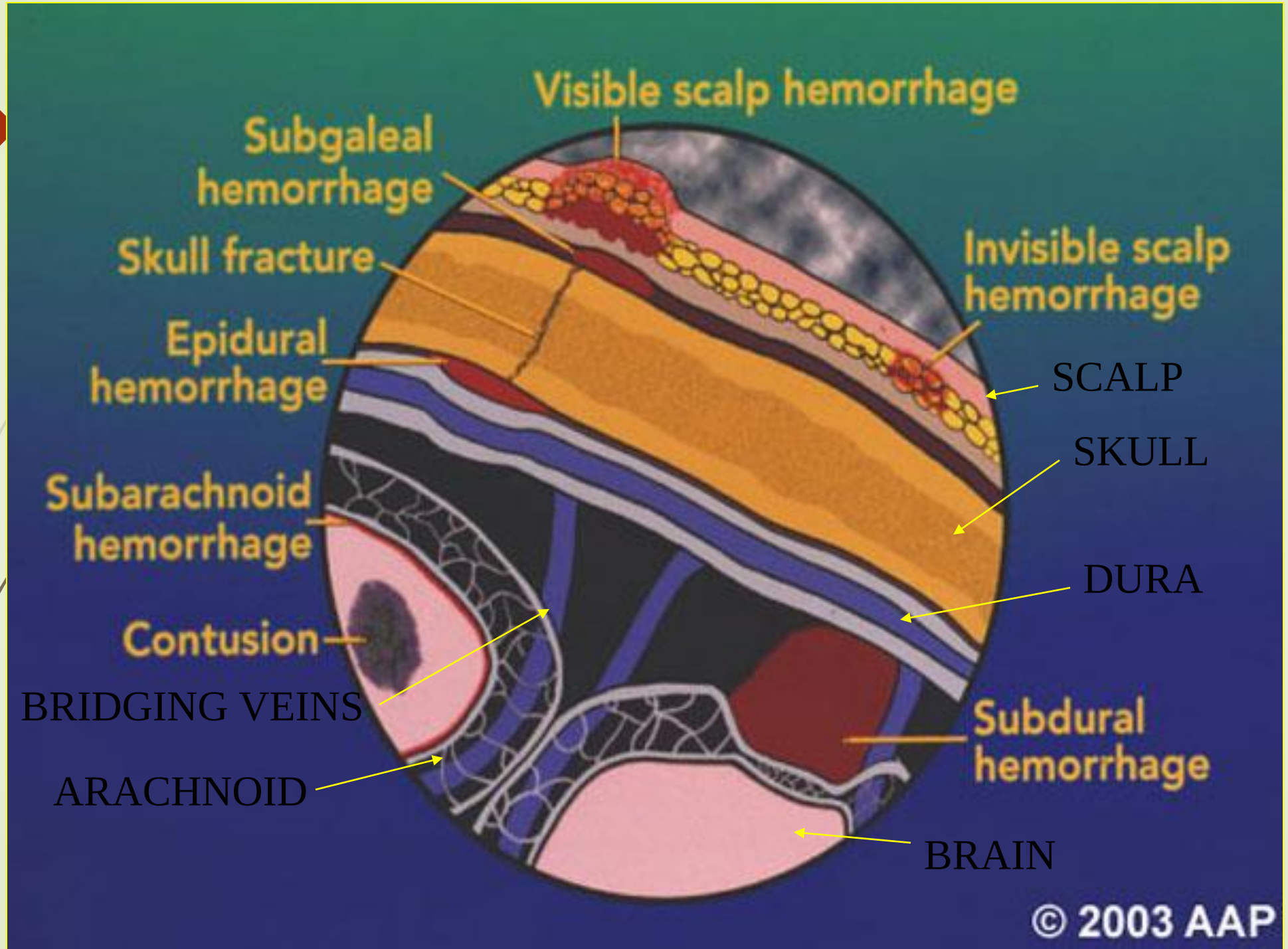
- An exception is the child with an epidural hematoma who may initially seem neurologically normal after the injury.

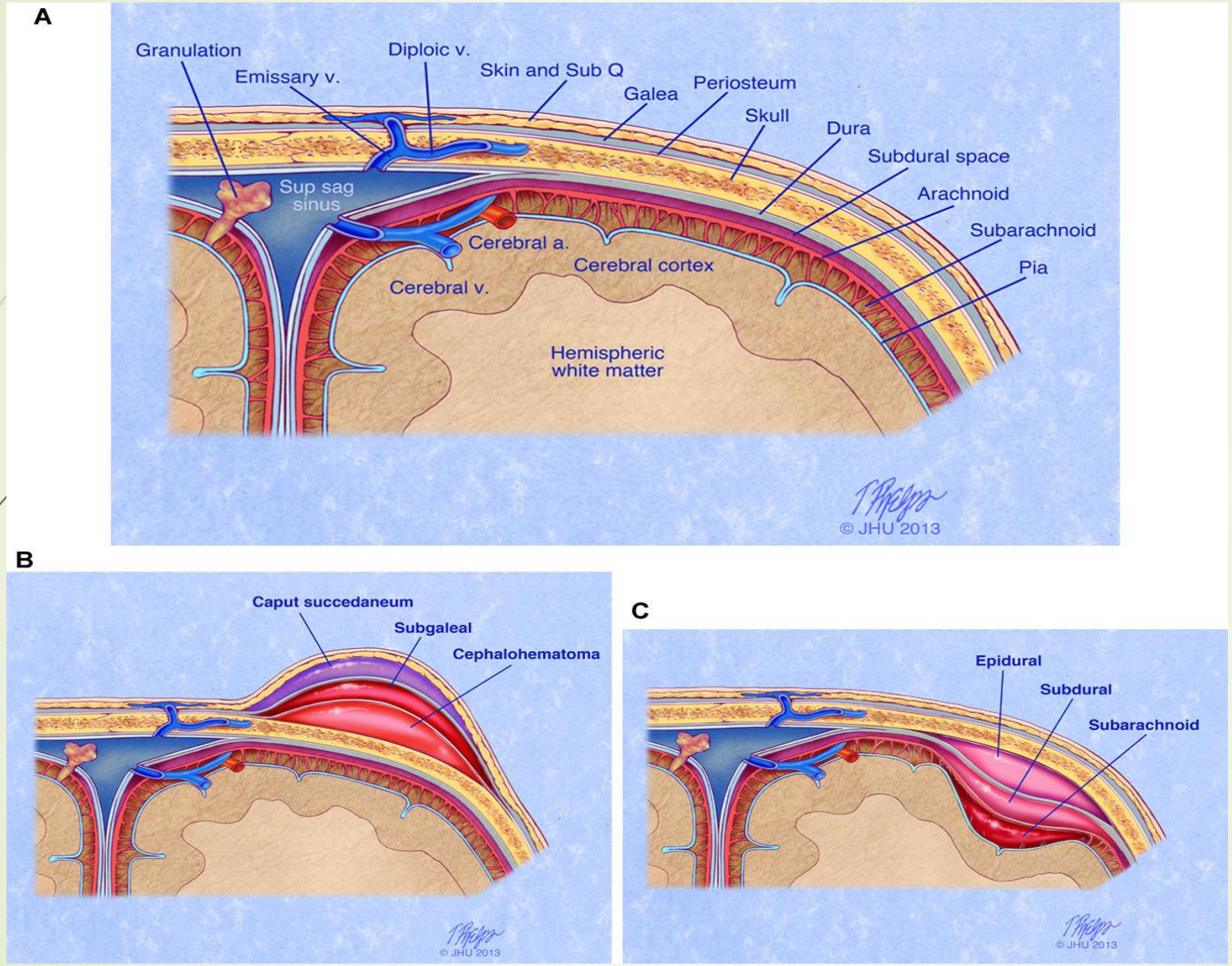
Timing of Injuries

- **Imaging**: can provide a broad estimate of timing
- **Clinical**
  - Immediate vs delayed
  - Focal injury with secondary systemic hypoxemia or ischemia, swelling, increased ICP etc
  - Most children who show delayed symptoms are not completely asymptomatic but may have persistent or recurrent non specific clinical signs such as vomiting, irritability, loss of appetite etc.
  - Trivial events cause trivial injuries. If a child is not immediately symptomatic from an accidental impact, it is (usually) a trivial event.

Location


Area of enlarged view
Scalp
Skull
Epidural space
Brain
© 2003 AAP


Visible scalp hemorrhage
Subgaleal hemorrhage
Skull fracture
Epidural hemorrhage
Subarachnoid hemorrhage
Contusion
Invisible scalp hemorrhage
SCALP
SKULL
DURA
BRIDGING VEINS
ARACHNOID
Subdural hemorrhage
BRAIN
© 2003 AAP


A
Granulation
Emissary v.
Diploic v.
Skin and Sub Q
Galea
Periosteum
Skull
Dura
Subdural space
Arachnoid
Subarachnoid
Pia
Sup sag sinus
Cerebral a.
Cerebral cortex
Cerebral v.
Hemispheric white matter
© JHU 2013
B
Caput succedaneum
Subgaleal
Cephalohematoma
© JHU 2013
C
Epidural
Subdural
Subarachnoid
© JHU 2013

Extracranial Injuries

- Alopecia: hair loss
  - Traumatic (hair pulling, traction)
  - Inflammatory
  - Autoimmune
- Subgaleal hemorrhage: bleeding under the scalp
  - Hair pulling
  - Impact
- Soft tissue injuries: often missed on exam


05—0100

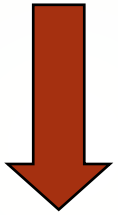

05—0100

Cranial Injuries

- Skull fractures
  - Simple (linear, non displaced)
  - Complex (comminuted, depressed)
- Evaluate by
  - CT (3D reconstruction)
  - Plain skull films
- Skull fractures do NOT heal with callus formation so are harder to date
- May be confused with: suture lines, vascular channels

Biomechanics of Head Injury

Cranial impact over a large area

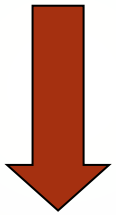


Linear skull fracture

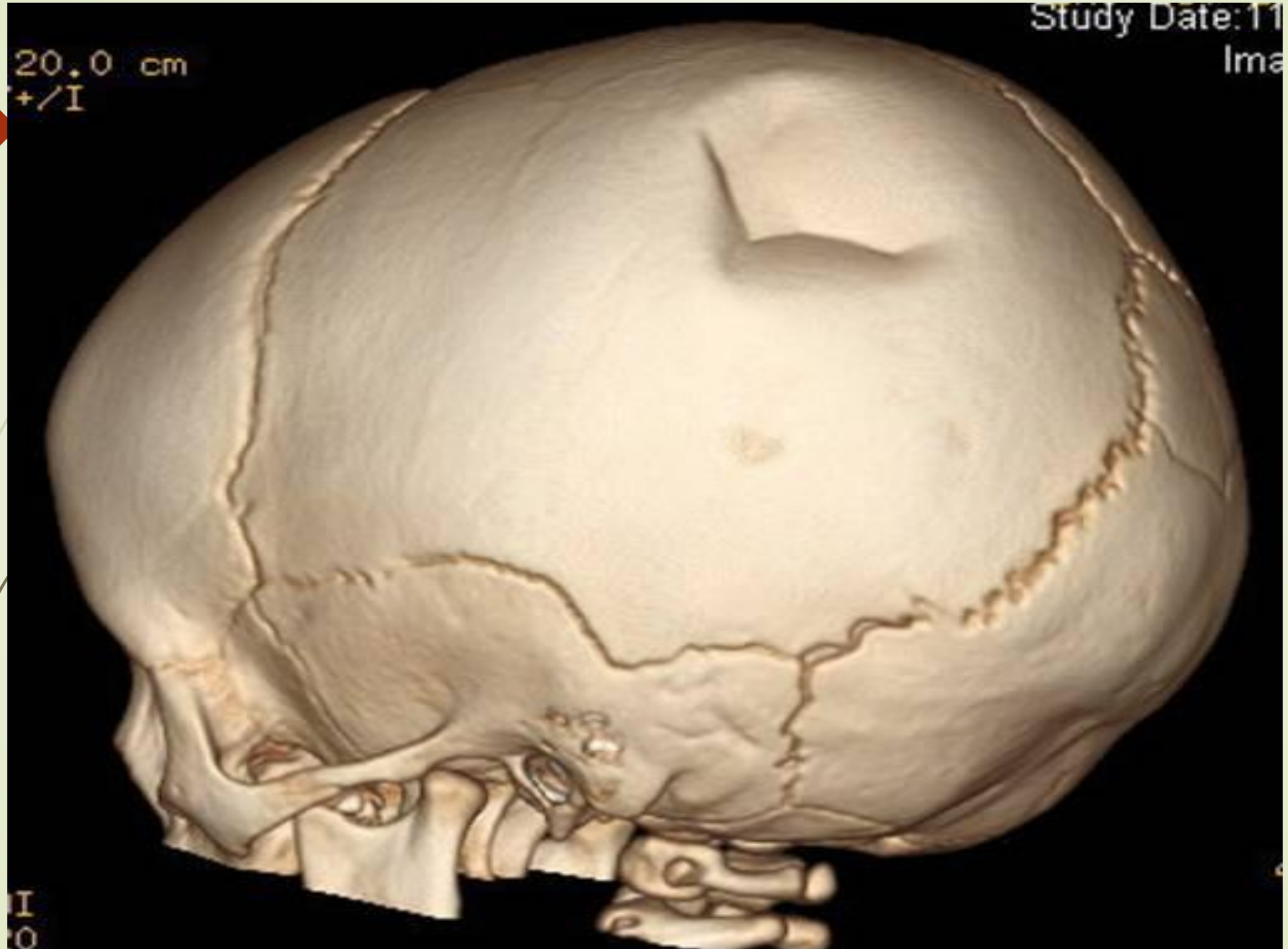

[HA]
[FP]

Biomechanics of Head Injury

Cranial impact over small area



Depressed or complex skull fracture.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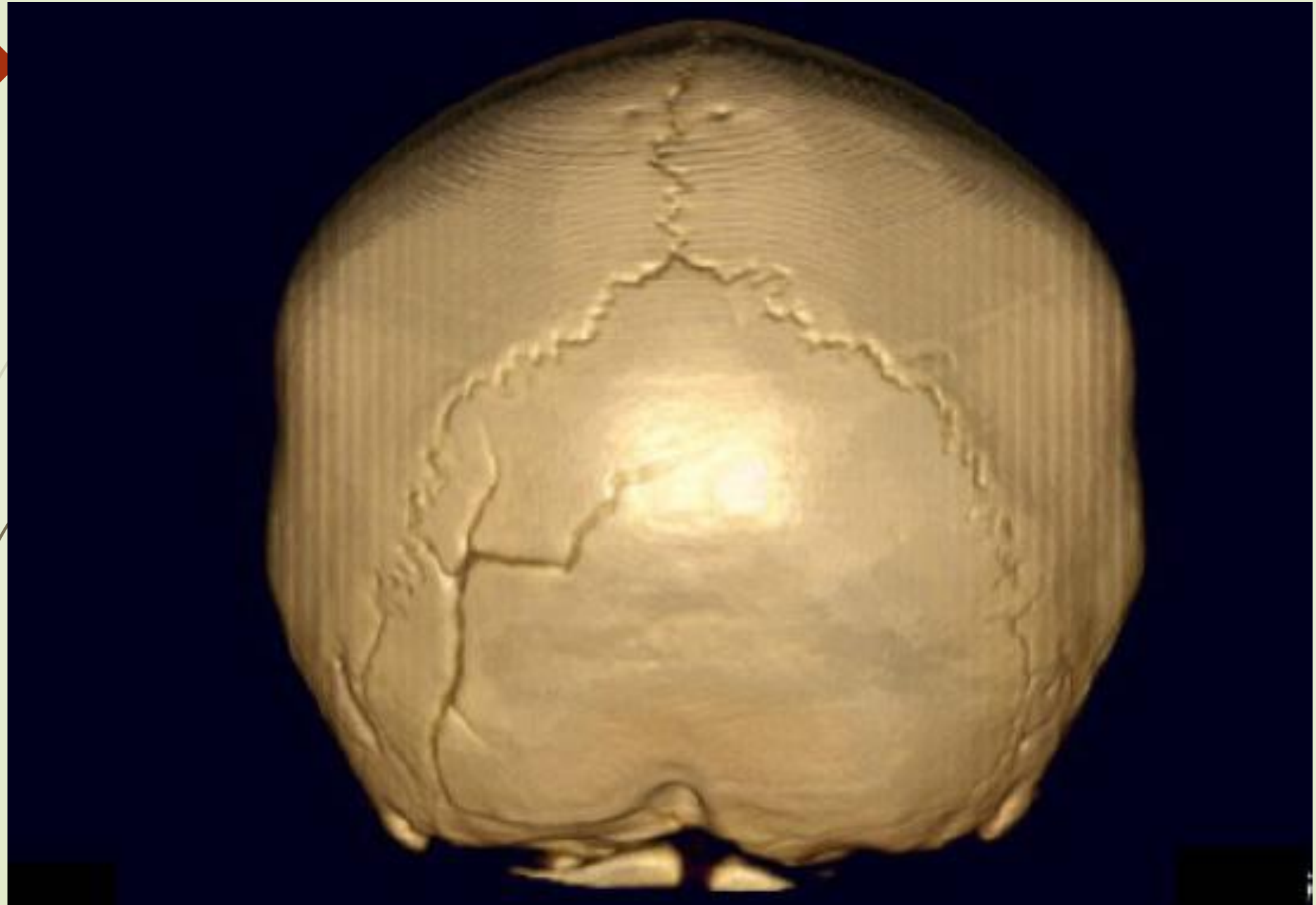
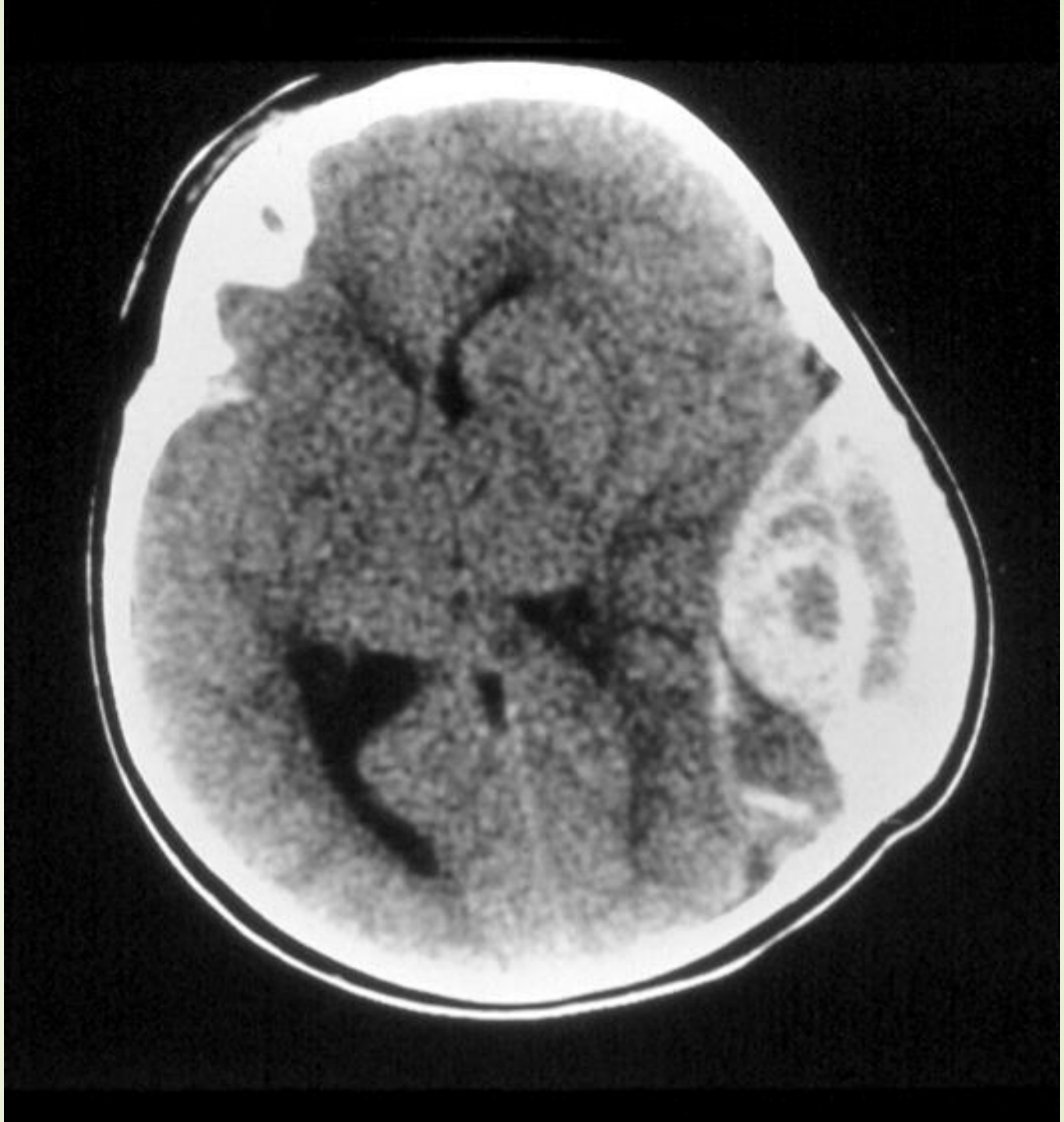


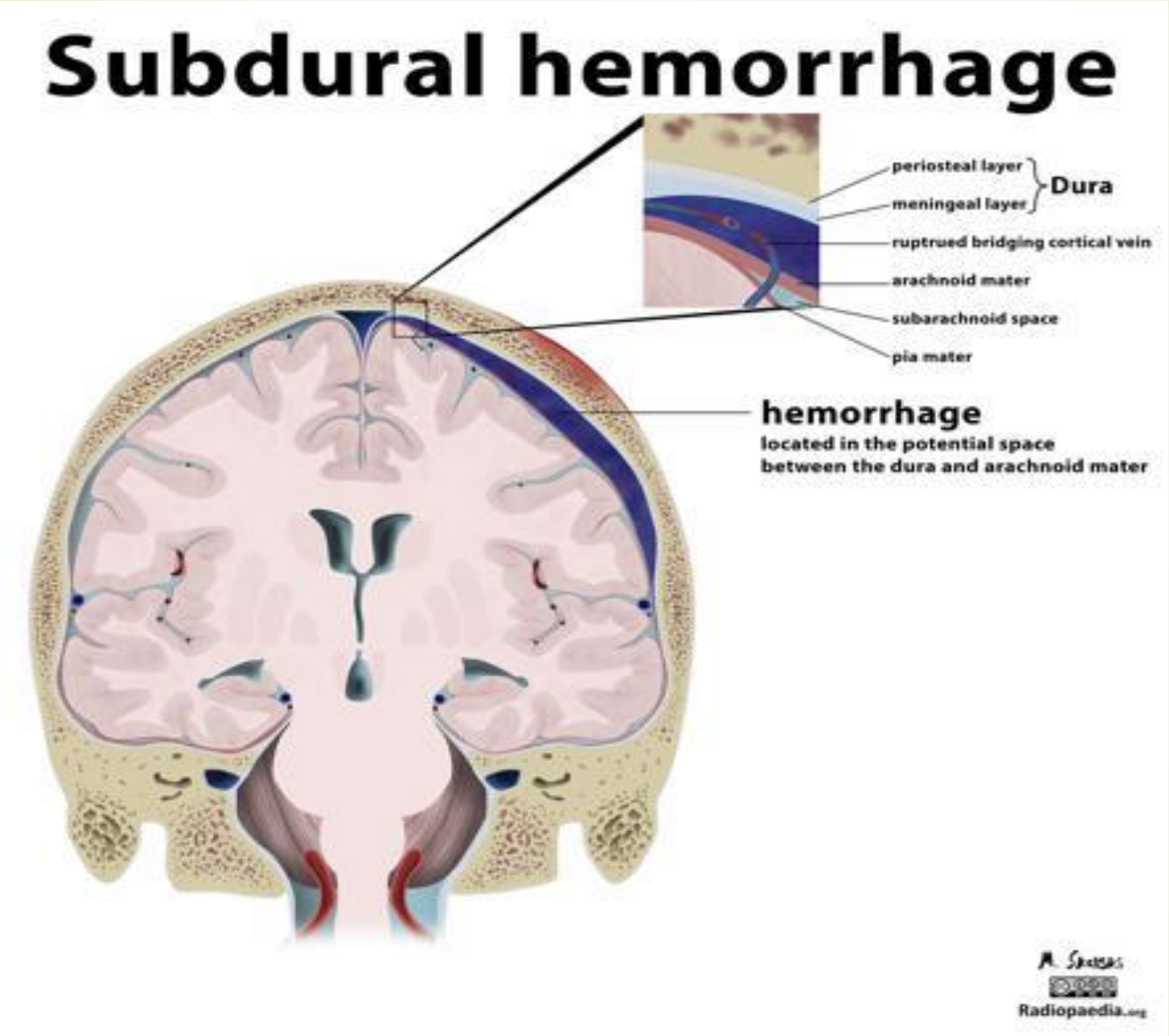
Intracranial Injuries

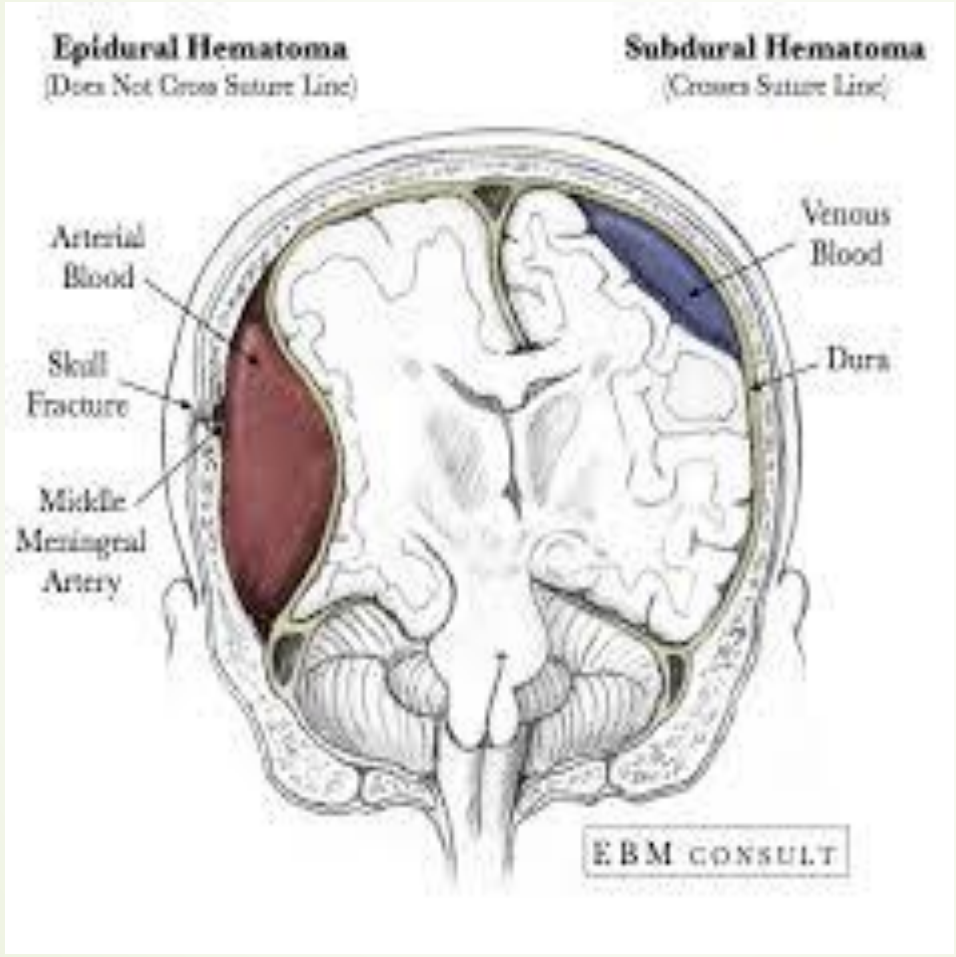
- Epidural hematoma
  - Impact injury; often associated with skull fracture
  - Usually an arterial bleed
  - Commonly accidental
  - Lucid interval may occur prior to onset of herniation symptoms *because the brain is not significantly affected*
  - Good outcome when treated promptly
  - Fatality occurs when there is progression to brainstem herniation.



Intracranial Injuries

- Subdural hematoma
  - Impact
    - focal, crush
  - Inertial (Shear) injury
    - diffuse
  - Usually small and not clinically significant – it is a marker of the type of force used.
  - Can be a ‘mass lesion’ associated with ‘mid line shift’
  - Aging by radiologic appearance (*) and/or by surgical findings.


Subdural hemorrhage
periosteal layer
meningeal layer
Dura
ruptrued bridging cortical vein
arachnoid mater
subarachnoid space
pia mater
hemorrhage
located in the potential space
between the dura and arachnoid mater
Radiopaedia.org


Epidural Hematoma
(Does Not Cross Suture Line)
Subdural Hematoma
(Crosses Suture Line)
Arterial Blood
Skull Fracture
Middle Meningeal Artery
Venous Blood
Dura
EBM CONSULT

Intracranial Injuries

- Subarachnoid Hemorrhage (SAH)
  - Subarachnoid space is CSF (cerebrospinal fluid) containing space
  - Normal enlargement of subarachnoid space in frontal area (BEES) can be confused with old blood. Look at previous head circumferences. Seen in infants ~3-6 months. Usually positive family history of big head
  - SAH often seen with subdural bleeds
  - SAH usually disappear quickly (2-3 d on CT).

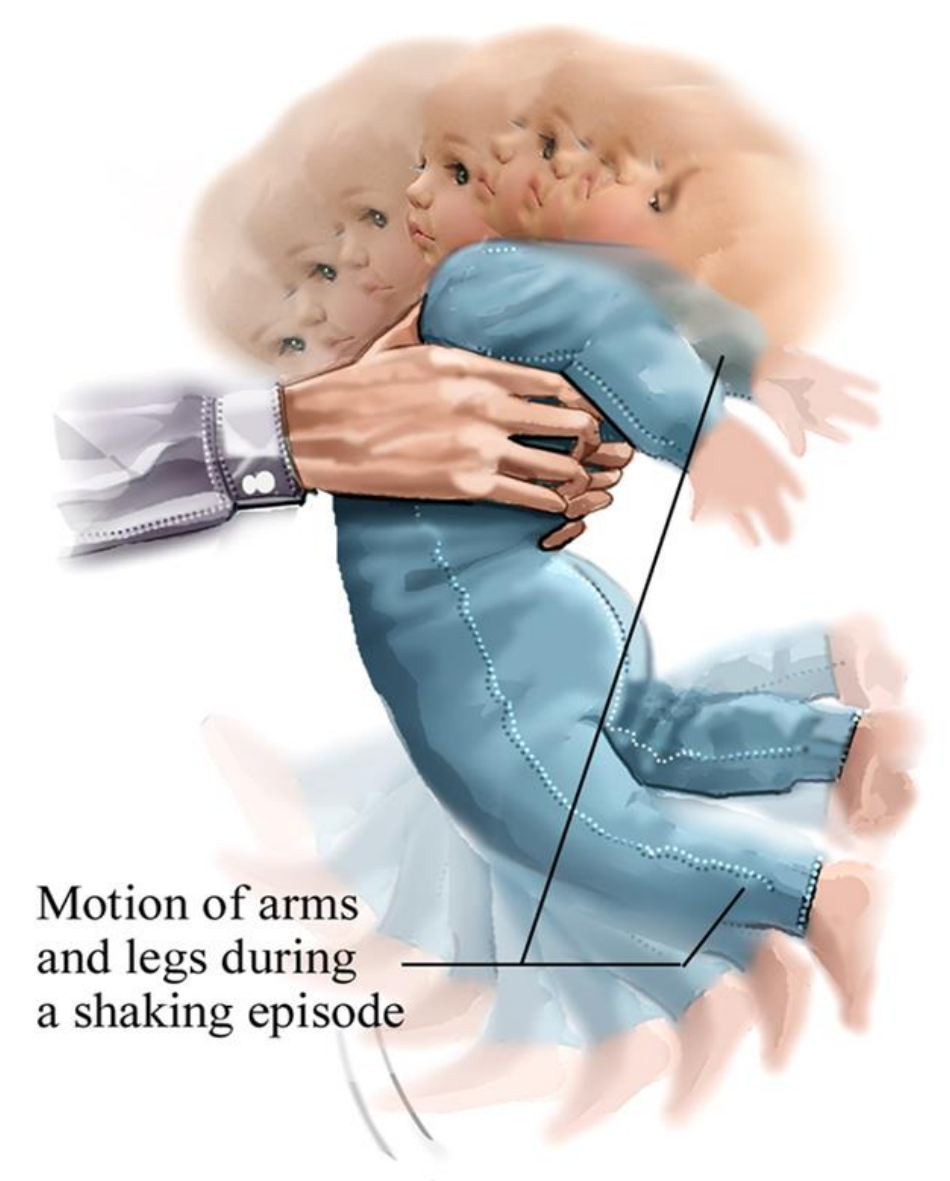
Intracranial Injuries

- Brain injury
  - Contusion (coup, contrecoup)
  - Shear injury, lacerations – from traction stress
  - Hypoxia/ischemia – from edema, cell damage, increased intracranial pressure, brainstem injury
  - Cerebral edema – non specific response to injury. Can develop quickly

Associated Injuries

- Fractures:
  - Rib - posterior
  - Metaphyseal
- Retinal hemorrhages
- Other injuries to head/neck

Fractures associated with AHT



Rib Fracture Injuries Associated with Shaken Baby Syndrome

Figure 1

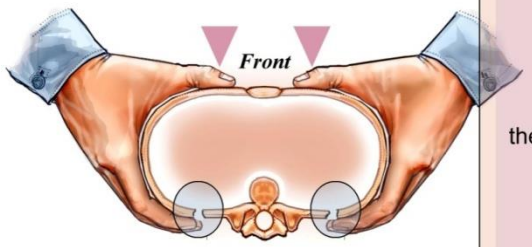


Figure 1 Injury

When an infant is shaken, the squeezing effect on the rib cage during the shaking episode can cause posterior rib fractures

Figure 2

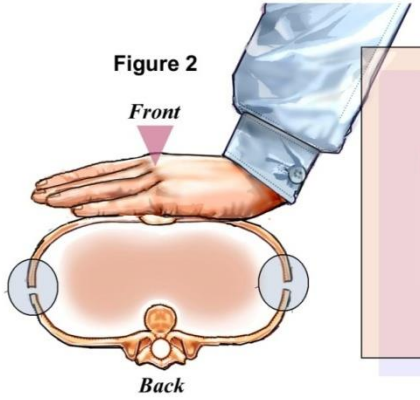
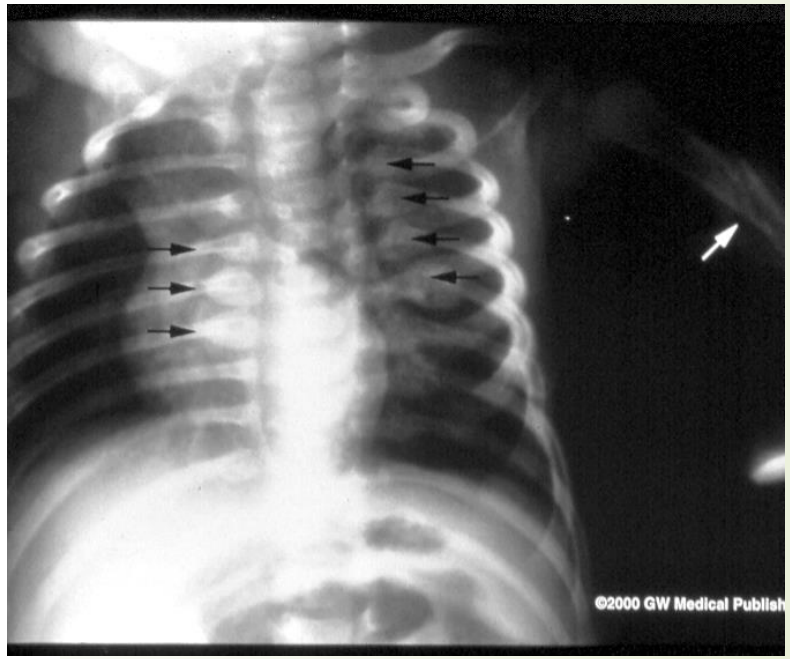
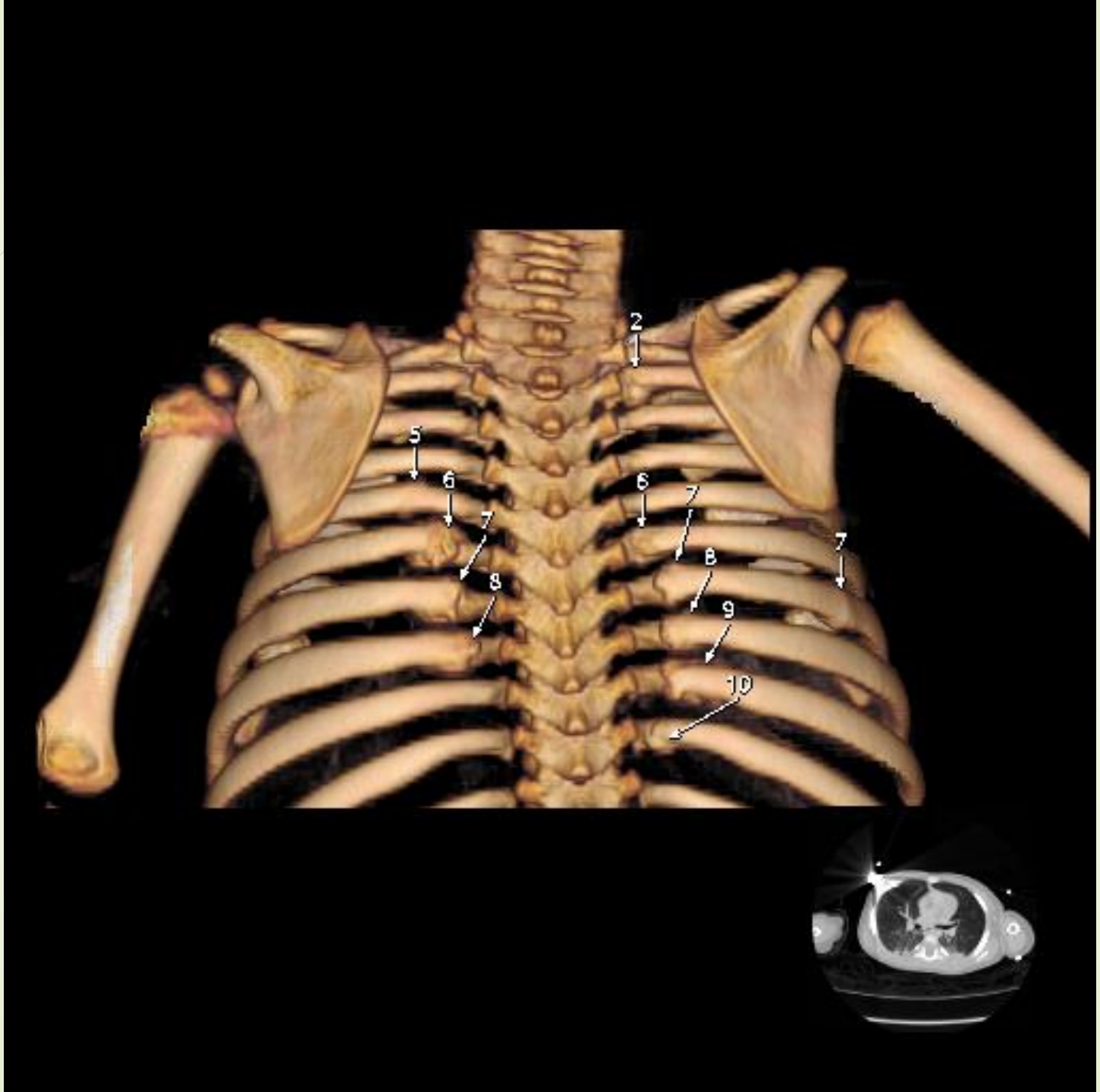


Figure 2 Injury

Pressure on the rib cage of an infant from the front can cause lateral rib fractures

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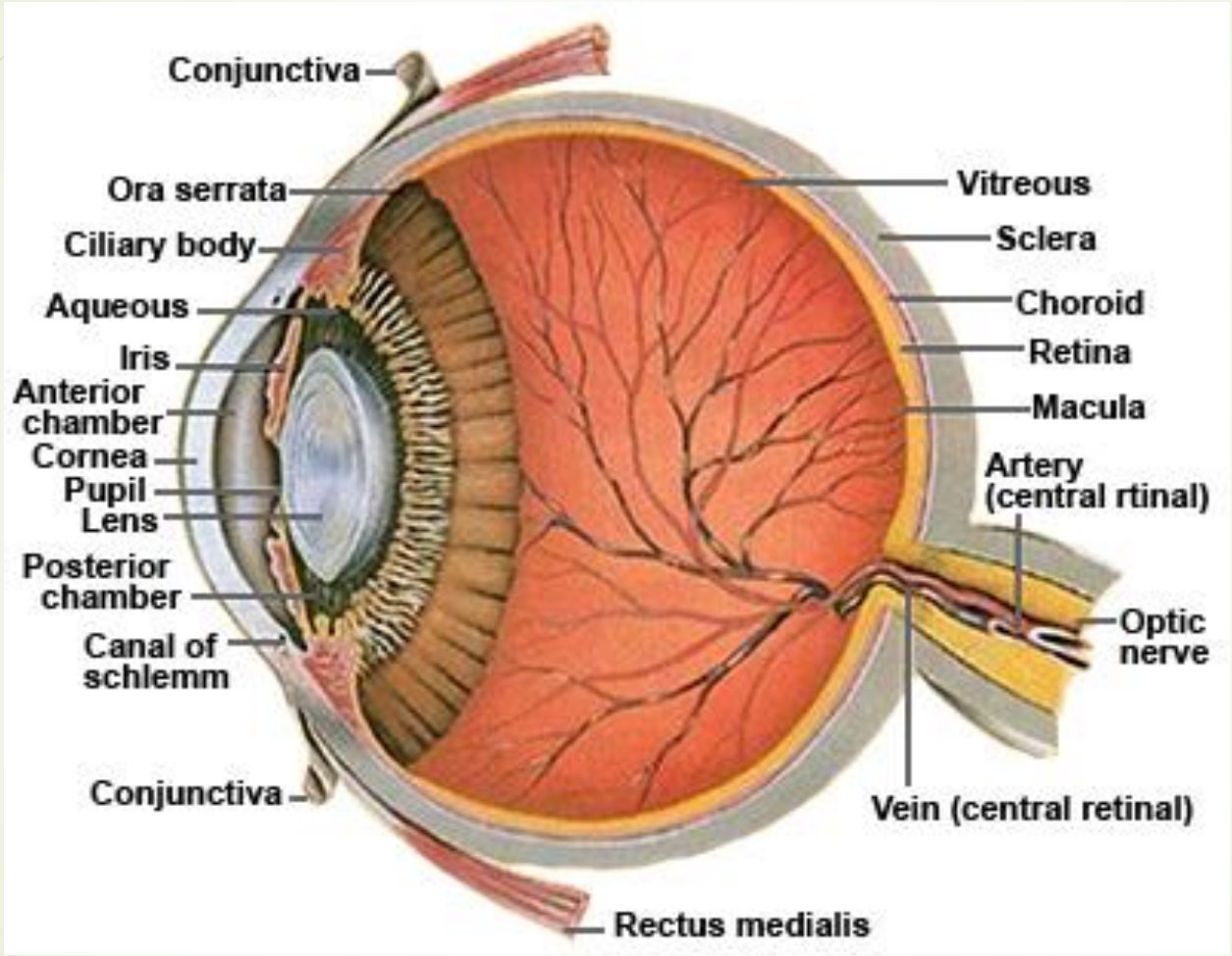
Retinal Hemorrhages

- Occur in many conditions
- Most common cause – birth
  - Resolve within two weeks (*)
- RH associated with inflicted head injury ***look different*** in location, distribution, than hemorrhages from most other causes.
- Retinoschisis (splitting of the retinal layers)
- NEED A PEDIATRIC OPHTHALMOLOGIST
- Cannot be dated.


Conjunctiva
Ora serrata
Ciliary body
Aqueous
Iris
Anterior chamber
Cornea
Pupil
Lens
Posterior chamber
Canal of schlemm
Conjunctiva
Rectus medialis
Vitreous
Sclera
Choroid
Retina
Macula
Artery (central rtinal)
Optic nerve
Vein (central retinal)

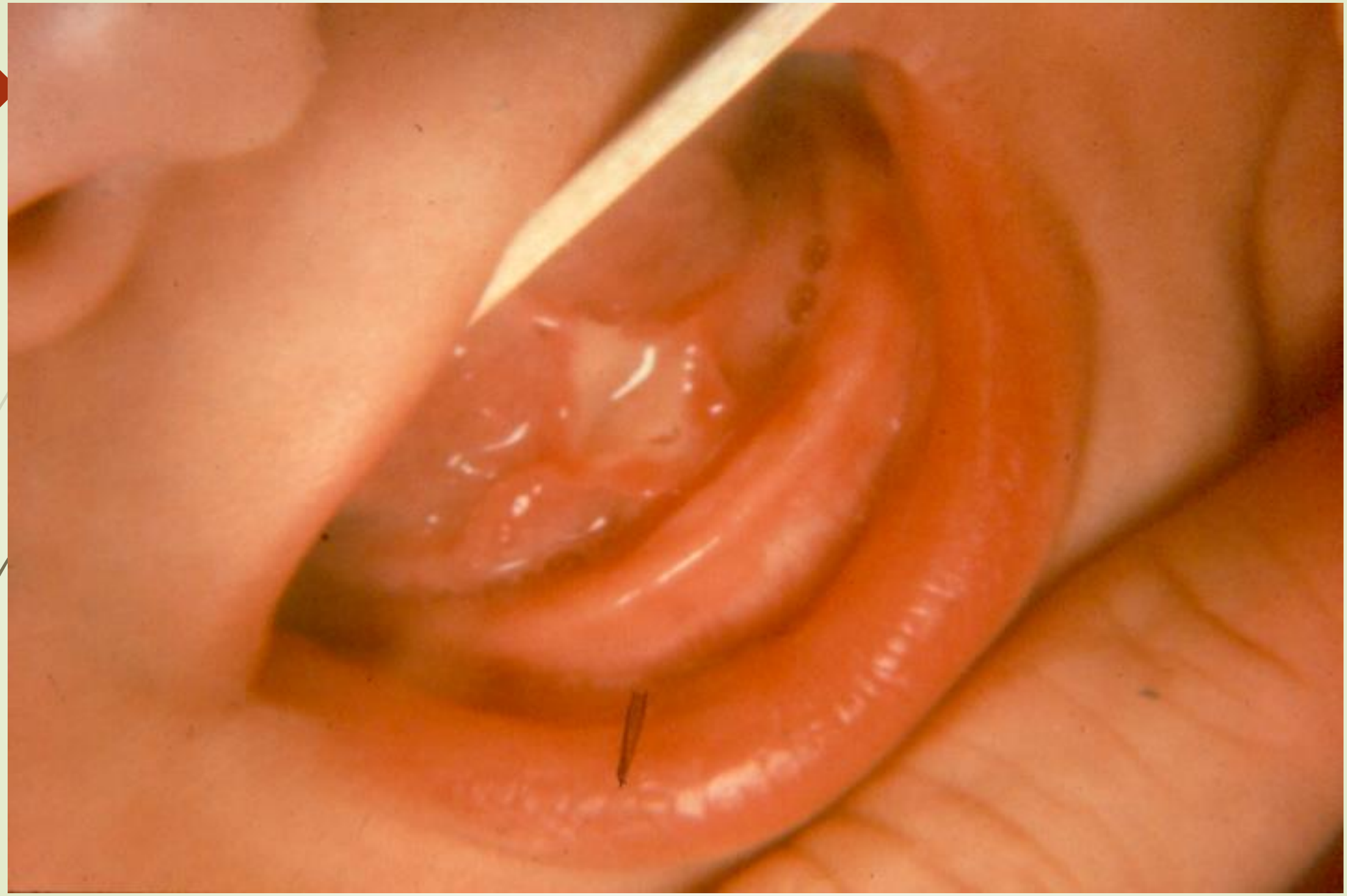
Retinal Hemorrhages

Differential diagnosis

- Multiple, multilayered
  - Birth related – clear within days
  - Crush injuries – easily determined by history, exam findings
  - Malignancy, infection, coagulopathy – identified on evaluation.
  - Severe accidental injury – easily determined by history, exam

- Few, in posterior pole
  - Minor accidental injury
  - CPR
  - Elevated intracranial pressure
  - Hypoxia

- Vascular anomalies – identified on imaging
- Genetic/metabolic disorders



Imaging Techniques

- First modality – CT head scan without contrast
- 3D reconstruction of CT is best for skull fractures
- MRI as confirmatory, 1-3 days after CT. MRI may be initial test

- *There may be a delay in appearance of head trauma on imaging studies*
- *Aging of blood on imaging studies is problematic*

Data Collection

- Accident history needs clarification
- PMH, FH, ROS should be obtained
- Dietary, development history
- Clotting disorders, genetic, metabolic, neurological, bone disorders
- Social history

Data Collection

- Complete Physical Examination
- Bruises, intraoral lesions, hidden head lesions under the hair
- Neck, ears
- Abdominal examination
- Genitalia, buttocks, posterior aspects

Data Collection

- Examination of the fundi with pupillary dilatation
- Photodocumentation
- Skeletal survey

Imaging Techniques

- CT of abdomen valuable because attention often diverted by HI
- *Skeletal surveys in all children < 2 years is indicated. Extend to 3 yrs if indicated*
- Acute rib fractures are typically NOT SEEN on xray but will be picked up when healing. ***Follow up skeletal survey in 2 weeks is necessary.***

- Most common histories:
  - Short fall (70%)
  - I don't know, I just found him this way
- Explaining Injuries by History
  - What primary injuries are present?
  - Contact or acceleration injuries?
  - What forces/circumstances are needed to produce these injuries?
  - Are these circumstances provided in the history given by the caretakers?

Obtaining the History

In getting history related to a fall, one should establish:

- When it happened
- What distance was fallen
- What surface was landed on
- What body part struck that surface
- When the child was last seen well
- When and how symptoms developed

AHT Differential Diagnosis

- Coagulation disorders
  - Hemorrhagic disease of the newborn due to Vitamin K deficiency
  - Other coagulopathies
- Genetic metabolic disorders
- Accidental injury
- Vascular anomalies

Controversies (a partial list….)

- Is shaking dangerous?
- Is impact necessary?
- Short falls
- Subdurals
- Biomechanics
- Retinal Hemorrhages
- Fractures
- Lucid interval
- Birth injuries
- Neck injuries
- Cerebral Sinus Thrombosis
- ‘Dysphagic choking’

Shaking vs shaken impact

- Biomechanical data re injury thresholds are based on studies in adult primates. Using adult injury thresholds on children – cannot scale down, does not account for differences in tissue composition, mechanical properties, and brain vulnerability
- These studies used single cycle rotational injuries; the effects of repetitive impulse loading are cumulative
- Secondary metabolic responses in infants appear to be qualitatively and quantitatively different than in older children and adults due to critical developmental periods during which the infant brain is uniquely susceptible to trauma. The developing brain sustains greater injury at a lower threshold than adult brain
- Signs of impact are often undetectable except at autopsy.

Short Falls

- Short fall is the initial explanation in ~70% of cases ultimately diagnosed as abuse

Fatal Pediatric Head Injuries Caused by Short Distance Falls

Plunkett, AJFMP 2001

- Review of USCPSC database for head injuries associated with playground accidents over 11 year period.
- 18 fall related head injury fatalities
  - Age range 1 year – 13 years
  - Distance 2 – 10 feet
  - 12 were witnessed by non caretaker
  - 12 had a 'lucid interval'
  - 4 had retinal hemorrhages (only 6 had fundoscopic exam)

Fatal Pediatric Head Injuries Caused by Short Distance Falls

- N= ? (>75,000 reports to CPSC)
- Age range; applicability to infant head trauma?
- RH documented in 4 children but NO exams by ophthalmologist
- Some complicated falls (swings, onto rocks)
- Two children with pre-existing conditions (TAR and AVM)
- Lucid interval – not seen in children who fell while swinging.

Deaths from Falls in Children: How far is fatal?

Chadwick et al J Trauma 1991

- 317 children with single falls:
  - 65 children fell 5-9 feet: no fatalities
  - 118 children who fell 10-45 feet; one fatality (from sepsis after prolonged hospital course)
  - 100 children who fell < 4 feet: 7 deaths (?!)

Annual Risk of Death Resulting from Short Falls Among Young Children

Chadwick et al

Pediatrics 2008

- Children from birth – 5 years
- Short falls (<1.5 m vertical height)
- Fatality rate <0.48/million children/year, or
- <10 children in the US every year will die from a short fall
- Concludes that fatal short falls are extremely rare

What about complicated falls?

In arms of caretaker

Down stairs

With momentum (swings)

Subdural Hemorrhage: defense arguments

- 1. Birth related asymptomatic SDH that rebleeds
- 2. Spontaneous bleeding in children with enlarged extra-axial spaces (BEES, BESS)
- 3. Sudden catastrophic decline related to ‘rebleeding’

Birth related SDH

- Two studies have demonstrated asymptomatic SDH in neonates:
- Looney et al (2007) found 16 cases of asymptomatic SDH in 96 neonates
  - All born by vaginal delivery, bleeds were infratentorial or low occipital (back of the head)
- Rooks et all (2008)
  - 46 of 101 asymptomatic neonates had SDH – supratentorial, posterior (back of head)
    - 94% resolved within 1 mo, 100% within 3 mo
    - None had a sudden collapse

Enlarged Extraxial Spaces:
Do these predispose to SDH?

- McKeag et al (2013):
  - 177 children with MRI evidence; 4 had SDH. One was thought to be from abuse; the others not
- Greiner et al (2013):
  - 108 children with enlarged EES; 6 had SDH (all asymptomatic); one thought to be due to abuse

- Subdurals CAN occur from birth, and CAN occur without major trauma, however these children are asymptomatic
- Most cases of abusive head trauma present with symptoms of traumatic brain injury and/or other (unrelated) injuries

Rebleeding into SDH

- Mechanism thought to be
  - 'neovascularization' (new blood vessels) which are more likely to bleed with minimal trauma
  - 'small brain in a big box': atrophy of the brain causing enlarged subarachnoid spaces, increased mobility of brain within the cranial cavity
- Associated with clinical deterioration when the rebleed becomes large enough to cause compression of the brain (space occupying). Uncommon and radiologically apparent

SDH rebleeding in abused children

Wright et al
Pediatric Radiology, 2019

- 85 of 160 children initially identified were re-imaged
  - 54 had evidence of rebleeding– all within the chronic SDH
  - Associated with large head, brain atrophy, larger SDH, enlarged ventricles
  - ***No child had new trauma, evidence of new parenchymal injury, or acute neurologic symptoms related to the rebleed***
  - Mean time of rebleeding was 12 weeks (not seen after 49 weeks)

Subdurals

- Small asymptomatic subdural hemorrhages can occur with normal delivery
- Small asymptomatic subdural hemorrhages can rarely occur in children with enlarged extra axial spaces
- CT imaging does not reliably estimate the age of subdurals

Biomechanics

- Heads are treated as a single mathematical point (oversimplification)
- Forces are complex (repetitive, movement in three dimensions, spinning and shearing forces) and not easily reduced to measurements such as ‘peak acceleration’.

"Lucid Interval"

- Time between injury and onset of S/S
- "Walk and talk and die"
- Not described in the pediatric literature except in epidurals
- "Lucid interval" hard to define in infants

Lucid Interval

- Why is it important?
  - Children often have multiple caretakers. Determining time (range) of injury may help narrow the list of possible offenders
- When do you see it?
  - Space occupying bleeds
  - Secondary brain injuries related to hypoxia, ischemia, edema (true lucid interval vs delayed LOC)

Neck injuries

- SCIWORA (spinal cord injury without radiographic abnormality)
- Injuries: ligamentous, spinal subdurals, cord laceration or contusion, nerve root avulsion
- MRI cervical or whole spine should be done in cases of AHT
  - If you don't look, you don't find
  - Estimated incidence 36-78% of AHT cases
- Autopsy studies that have looked at the spine have found evidence of neck/spine injuries in the majority of cases of children with head trauma

Cerebral Sinus Thrombosis

- Chaudhary et al: Venous injury in abusive head trauma. Pediatric Radiology 2015
  - 45 children (age 15 days to 31 mo) with AHT
  - MRI venography showed mass effect (from adjacent SDH or brain swelling) on venous structures in 69%.
  - Primary cerebral sinus thrombosis is rare (2-7 cases/million), and usually associated with systemic illnesses (dehydration, infection, heart disease, head trauma, clotting disorders) which are identifiable

Trauma/Neglect and Brain Development

- Nature vs Nurture
- Brain development is stimulus dependent
- Profound effects of early experience and environment on expression of genetic potential
- Infancy and early childhood is time of greatest susceptibility to experience

SBU Assessment

Traumatic Shaking

The role of the triad in medical investigations of suspected traumatic shaking

Swedish Agency for Health Technology Assessment and Assessment of Social Services
2016

Triad

- Subdural hematoma
- Retinal hemorrhage
- Encephalopathy

SBU Objective

- To determine the diagnostic accuracy of the triad in detecting that an infant had been violently shaken
- Methods: literature review
  - 3773 abstracts, 1064 found to be possibly relevant, 30 included, and only two found useful (moderate risk of bias)
- PIRO

  Population: children < 12 months old

  Index Test: the 'triad'

  Reference/gold standard: witnessed or confessed shaking

  Outcome: diagnostic accuracy

SBU Conclusions

- There is limited scientific evidence that the triad and therefore its components can be associated with traumatic shaking
- There is insufficient scientific evidence on which to assess the diagnostic accuracy of the triad in identifying traumatic shaking.

SBU report concerns

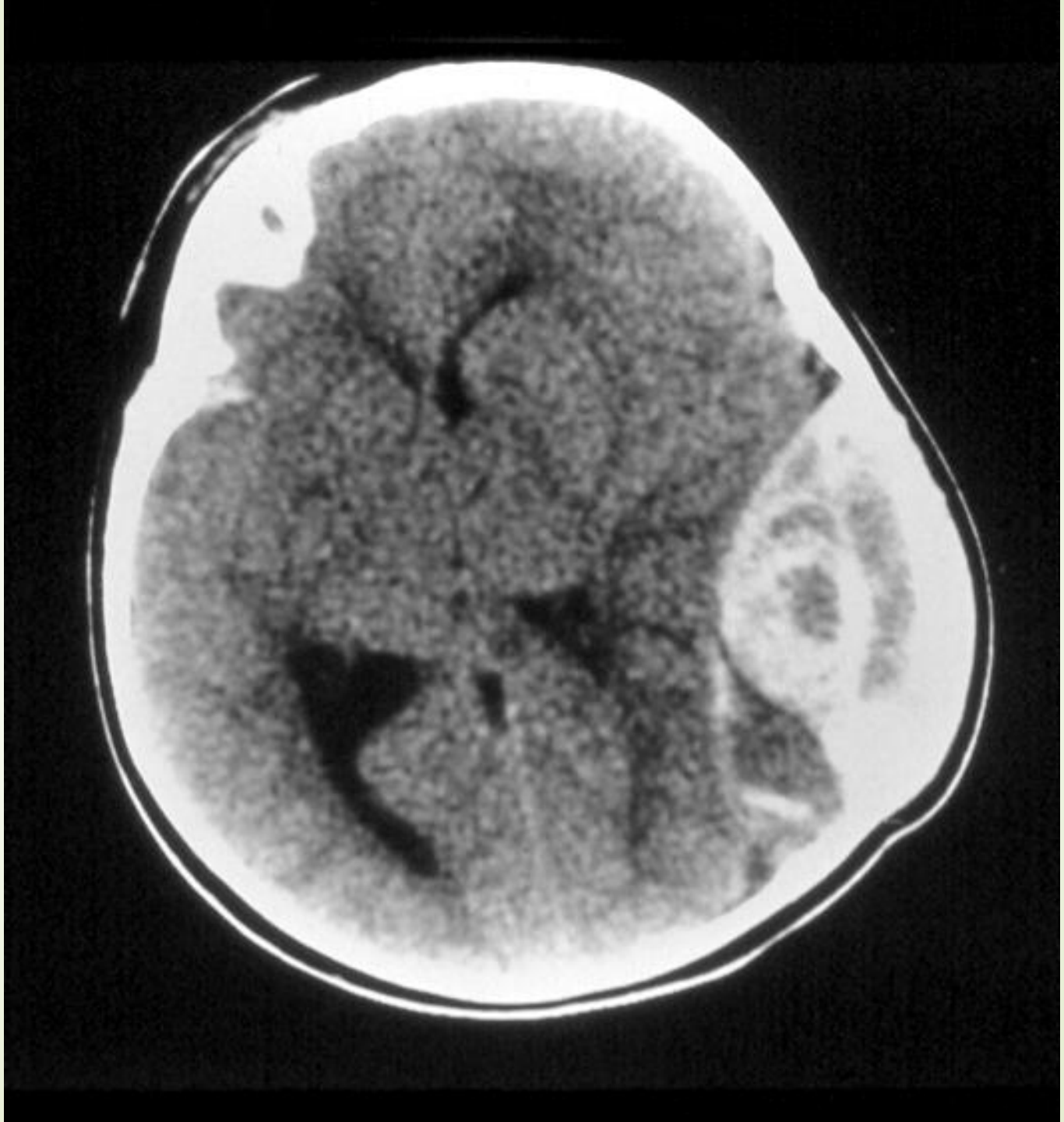
- 'Impossibly strict criteria' (only witnessed or confessed cases; excluded children with other injuries)
- Retinal hemorrhages, subdurals used generically
- Literature misrepresented
- Inequitable application of study standards (papers acceptable only if >10 cases but single case reports of alternative diagnoses accepted)
- Straw man argument: the 'triad' as index test – this is NOT a medical diagnosis
- No child abuse professionals involved
- Peer review by pediatric professionals rejected

Read about it

- The full SBU report is available on line
- The responses are all available online at Acta Pediatrica 2017 – open access

Case 1

- 7 yr old boy falls off bike
- Goes home complaining of headache; eats lunch
- 2 hours later vomits followed by progressive confusion and lethargy, abnormal gait
- Taken to pediatrician > blown pupil >> to ED
- CT demonstrates expanding epidural hematoma with impending herniation
- Hematoma surgically evacuated and does well



CASE 2

- 9 month old male twin, previously healthy
- Lived with mom, boyfriend x 6 months
- URI symptoms, fussy x 2 days
- Mom left for work 0800; fed twins prior to leaving
- 1300 boyfriend called mom; baby 'not looking right'; vomited. Mom called 911

CASE 2

- Paramedics arrive 1309; found child on LR couch. "Agonal breathing", unresponsive
- Arrive ED 1325; GCS 6 (response to pain)

  (Glasgow coma scale: motor, verbal, eye opening response. Max score 15)
- CT: cerebral edema, loss of grey white differentiation; small subdural bleed
- Ophthalmology: diffuse RH bilateral, extensive
- Skeletal: healing posterior rib fractures; metaphyseal fracture proximal tibia

Case 2

- History
  - 2 days prior, fall down stairs. Seemed fine afterward
  - 1 hour prior to calling mom, fell off couch – cried then calmed
  - Boyfriend fed child after fall off couch - normal
  - No injuries to twin

Case 2

- Taken off life support the following morning
- Autopsy: blunt forced head injury; homicide
- Issues:
  - mechanism of death
  - timing

Case 2

- Possible defenses
  - Birth related injury
  - Short fall injury
  - *Rickets (or similar brittle bone defense)*
  - Genetic-metabolic defect
  - Second impact
  - Abuse but somebody else did it

Case 3

- 2 year 9 month old boy
  - Wednesday – awoke with headache, not wanting to play. Went to pediatrician. Dx viral infection
  - Thursday – worsening headache, vomiting, not wanting to walk – to ED. Dx viral infection
  - Friday – progressively worse, back to pediatrician. (viral infection)
  - Saturday – blown pupil >> to ED where emergency CT demonstrated large unilateral subdural. Transferred to PCH for emergency surgery
  - GCS on admission 8. No external signs of trauma. Posturing

Case 3

Considerations:

- Subdural hematoma
  - mechanism/s?
- No history of injury
- Promptly sought care
- History of prior event
- Absence of other injuries
- No priors
- Unilateral…….

Differential diagnosis?

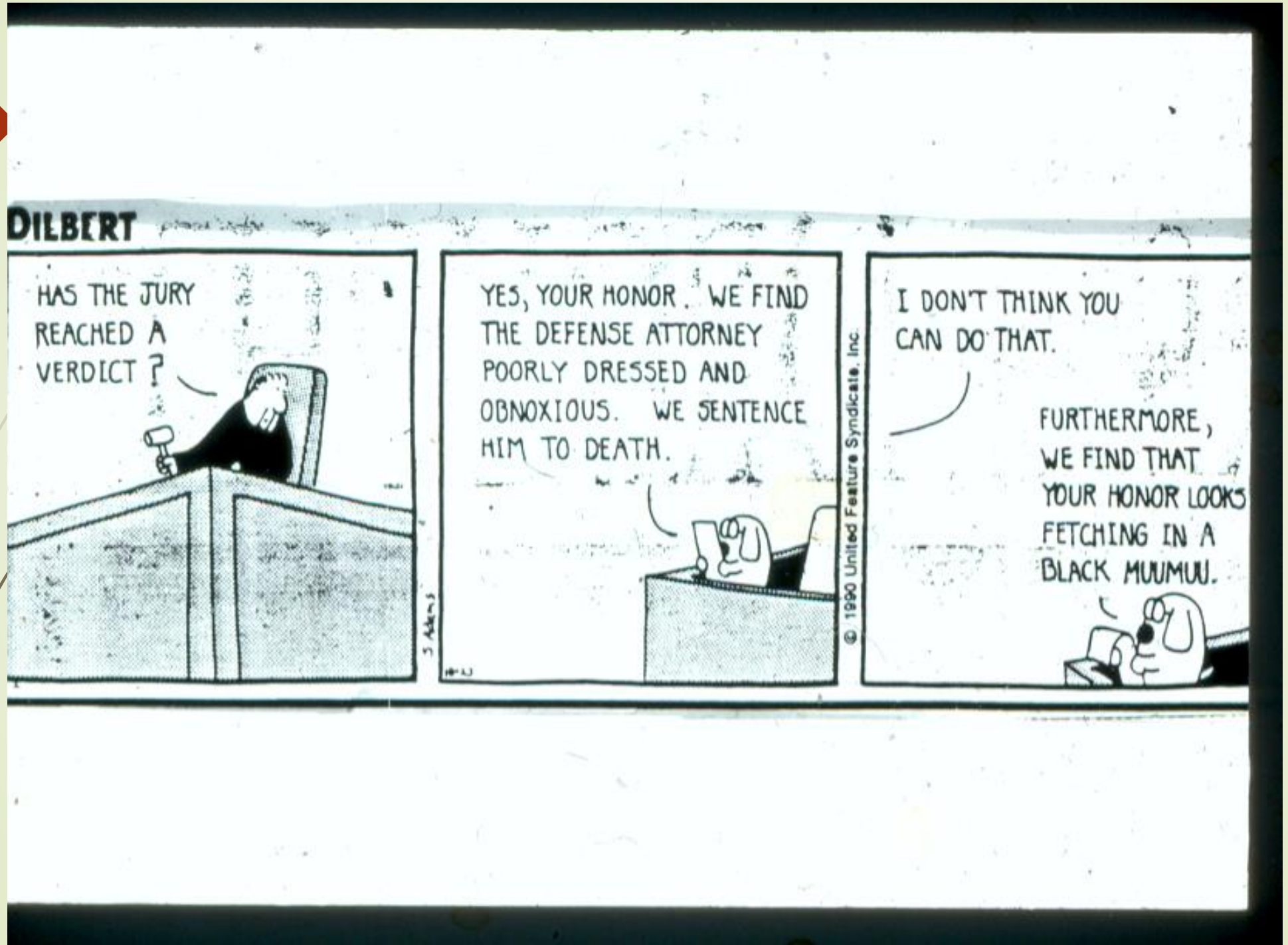
Case 3

- Past history
  - Similar episode of headache a month before, seen by pediatrician but fine at time of visit
- Social history
  - Lives with parents and 11 year old brother.
  - Parents unemployed; mom is primary caretaker
  - No prior reports


[A]
[P]

Case 3

- Diagnosis: Subarachnoid cyst
- Drained and did well clinically
- One month later readmitted with recurrent bleed


DILBERT
HAS THE JURY REACHED A VERDICT?
YES, YOUR HONOR. WE FIND THE DEFENSE ATTORNEY POORLY DRESSED AND OBNOXIOUS. WE SENTENCE HIM TO DEATH.
I DON'T THINK YOU CAN DO THAT.
FURTHERMORE, WE FIND THAT YOUR HONOR LOOKS FETCHING IN A BLACK MUUMUU.
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